UNITED STATES DEPARTMENT OF AGRICULTURE
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IAROVIZATION IN FIELD PRACTICE

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Division of Cereal Crops and Diseases 1/

Iarovization is a method of treating seed of winter cereals so they may mature from spring sowing and of treating seed of spring cereals and certain other spring crops to accelerate reproduction and maturity. It has recently been reported to be widely used in Russia. Popular or semitechnical articles discussing the methods and effects of, and the possible or assumed benefits from, iarovization have appeared in Russia, Germany, England, Canada, the United States, and probably elsewhere.

The purpose of the present discussion is (1) to call attention to certain difficulties and limitations in the practical application of iarovization; (2) to report the results of early trials of iarovization in this country; (3) to present comparative yields of "naturally iarovized" winter wheat and of untreated spring wheat; and (4) to point out that the high temperature treatment has failed to produce the responses claimed by the proponents of iarovization in crops such as sorghums. These facts should be available to everyone contemplating trials of iarovization.

Other names and spellings recently used for iarovization are yarovization, jarovization, iarovatsii, springification, springization, and vernalization.

WHAT IS IAROVIZATION?

Iarovization is a slow and limited germination of seeds at certain controlled temperatures (18,19,21,22,23,28) 2/. The seeds are first wetted to start germination but the later progress of germination is greatly retarded by low temperatures, limited moisture, or salt solutions. The small grains-wheat, oats, and barley- are held at comparatively low temperatures ranging from 32 to 41° F., while such seeds as corn, sorghum, and millets are maintained at higher temperature ranges (68 to 86° F.) The latter seeds, according to published recommendations, must be germinated in darkness. The treatment, under the controlled conditions, is continued for periods of 5 to 65 days,

1/ The writer wishes to acknowledge the assistance of several associates in the Division of Cereal Crops and Diseases in furnishing data, information, and suggestions.

2/ Underscored numbers in parentheses refer to Literature Cited, p. 11.

depending upon the crop, after which time the slightly sprouted seeds are ready for planting. According to the theory, these slightly sprouted seeds, being in fact very young seedlings, have already had their requirements for cold, darkness, or what not, completely satisfied by the treatment so the plants will mature earlier than from untreated seeds, or in case of winter grain will mature from spring sowing.

HISTORY OF LOW TEMPERATURE IAROVIZATION

Many supposedly new discoveries are in fact revived old ideas. Thus, low temperature iarovization is merely an old and well-known seed treatment masquerading under a new name. It has been common knowledge for more than a century that winter wheat seeded in the spring ordinarily will not head completely, but if seeded in the late fall, winter, or very early spring will emerge in the spring and usually will head normally and make a fair crop if conditions are favorable. As long ago as 1793 winter wheat was known to reach maturity in England from sowing as late as February, and 10 years later was reported to have been grown successfully from March seeding.

The very late sowing of winter wheat so that it would not emerge until late winter or early spring was reported to have been generally practiced in Great Britain about 1840 (3). The practice, also seems to have been followed with varying degrees of success or failure by many farmers in the United States during the period from 1832 to 1840 (4). Late sowing was believed to reduce injury from freezing and Hessian fly but to result in delayed maturity and consequent increased injury from rust and "blight". In the semiarid sections of the United States in certain seasons large areas of winter wheat have been harvested that had emerged in the spring after being sown in dry soil in the fall. Natural iarovization from late seeding was observed by the writer under experimental conditions as early as 1915 (20) and has frequently been reported by others as will appear later.

The writer also observed a complete collection of American varieties of winter wheat headed in mid-July from sowing about April 20, 1920, at Burns, Oreg., where spring and summer temperatures are low, while the same varieties sown a month earlier at Moro, Oreg., where the temperatures were much higher, did not head.

It has long been assumed that small grain crops are favored by cool temperatures in the early stages of growth and this also has been demonstrated experimentally (13). The literature on the effects of temperature and light upon the wheat plant already has been well summarized (8, 12) and need not be repeated here.

The fact that the low temperature requirement of winter cereals can be satisfied in the early stages of germination has been known at least since 1837. In June of that year the editorial quoted below appeared in The Cultivator (1):

"A gentleman of high respectability informs us, that the following mode of sowing winter wheat in the spring, has been partially adopted in Tennessee, with the happiest success. In early winter the seed grain is put into casks, and water enough added to soak and cover it. It is then exposed so that the water becomes frozen, and it is kept in this state as far as practicable until the soil is fit for its reception in the spring. It is well known that the operation of frost upon the seed of winter grain has the same effect as if it is sown in autumn - as wheat and rye sown at the setting in of winter will grow and mature. The advantages which are experienced from sowing in the spring are, 1st, that the grain is not subject to be winter killed; 2nd, it escapes the Hessian fly in autumn, and possibly it may escape it in the spring; 3rd, the ground being fresh stirred for spring sowing, the growth will be more vigorous; and 4th, as it will come into ear late, there is at least a probability that the crop may escape the grain worm. The advantages are so manifest, that the experiment is worth a trial; and we shall feel obliged to some Tennessee correspondent who will give us the details and result of the practice in that State".

In February 1837, Col W. Abbott (2) soaked some winter wheat to start germination, stored it at freezing temperatures for about six weeks, and sowed it in Onondaga County, New York, on April 12. The wheat headed irregularly the following summer. Two years later the editor of The Genesee Farmer (2) in commenting upon the experiment stated:

"All acquainted with new countries, are aware that the clearing of lands is at times so delayed, that the wheat sown in the fall, does not come up; it only swells, sprouts slightly, but does not show itself above the surface; in this state it is exposed to the frosts of the winter, and remains without further progress till the warmth of the spring brings it forward in common with the earlier sown wheat. The same effect is produced by the process described in the letter of Col. Abbott."

In 1849 Allen (7) stated:

"The only division necessary for our present purpose is of the winter wheat (Triticum hybernum), and spring or summer wheat (T. aestivum). The former requires the action of frost to bring it to full maturity, and is sown in autumn. Germination before exposure to frost, does not, however, seem absolutely essential to its success, as fine crops have been raised from seed sown early in the spring, after having been saturated with water and frozen for some weeks. It has also been successfully raised, when sowed early in the season, while the frost yet occupied the ground."

It is thus seen that a process very similar to what is now called iarovization was well described in a standard reference book on agriculture published 84 years ago.

In later years variations of Abbott's experiment were tried by others (17) with more or less indifferent success.

Results of two early iarovization experiments reported in 1861 and 1868, respectively, are quoted below:

"J. C. Bishop, Fond du Lac Co., Wis., writes to the Agriculturist that he has frequently sown small quantities of winter wheat in spring, and obtained a good yield the same season, by putting it in very early and wetting the surface of the ground thoroughly, so that the wheat will be soaked and frozen". (5)

"I once tried an experiment by sowing winter wheat after the growing season was ended, and the ground about to freeze up - - - the young plants stood unusually thin on the ground--not one of them tillered at all; the straw grew very coarse, the heads were short, the grain shrunken and small, and the stems and leaves were so badly affected with red rust, that I never cared to repeat a similar experiment". (26)

The latter experiment was reported in a well-known book on wheat by Todd (26), published 65 years ago. There appears to have been very little interest in iarovization during the following 50 years. The most complete and definite experiments in the iarovization of wheat, rye, and barley, previous to the past decade, seem to be those reported by Gassner (11) in Germany in 1918. Most iarovization experiments since that time appear to be largely repetitions, elaborations, or refinements of Gassner's discoveries. Kidd and West (15) in 1919 reported results with winter rye and oats in England, similar to those obtained with winter grains by Gassner. In both Gassner's and Kidd and West's experiments the seeds were allowed to produce sprouts 2 to 2.5 cm in length before planting, whereas both the earlier and recent workers cited permitted the seeds to sprout only slightly.

A farmer in Montana rediscovered the iarovization response by accident. He treated some wheat with the ordinary formaldehyde solution so late in the fall that the ground froze immediately afterwards and prevented seeding. The wet seed was kept over winter, most of the time in a frozen condition, and produced a crop from spring seeding. On the basis of this and other experiences, together with the knowledge of some of the results previously cited, agronomists at the Montana Agricultural Experiment Station, in the fall of 1922, started an investigation of the effect of soaking and freezing winter wheat upon the growth habit. 3/ The periods of chilling in most of the experiments apparently were too short to produce satisfactory heading of spring sown winter wheat (14), but after some of the longer exposures to cold there was an indication of a partial iarovization response.

An attempt, more than 10 years ago, to iarovize winter wheat artificially by the late H. M. Woolman, of the Division of Cereal Crops and Diseases, was a failure because the seeds all decayed.

Additional observations and experiences could be given but enough has been cited to show that the knowledge of low temperature iarovization has not been acquired recently.

3/ A report of these experiments was furnished to the writer by Clyde McKee, Agronomist, Montana Agricultural Experiment Station.

EFFECT OF IAROVIZATION ON YIELDS

If iarovization is to prove a successful agricultural practice for winter grain it must result in better yields than can reasonably be expected from the use of spring varieties. It is not sufficient to show an improvement as compared with non-iarovized seed of winter grain for the reason that spring varieties are available for all sections of the United States where iarovization might be expected to prove useful. Such fragmentary evidence as is available in the literature does not meet this issue in a satisfactory manner and hence requires no further attention in this connection.

Probably the most satisfactory experimental evidence in this country is the comparative yields of winter wheat which seeded in the fall did not emerge until spring, as compared with spring varieties seeded at the normal dates for spring seeding. Several comparisons of this kind are available from field stations of the United States Department of Agriculture and from State experiment stations. The average yields from 62 such experiments are given in table 1. Many of these data have appeared previously in greater detail in publications presenting results of cereal experiments at each Station. (8, 9, 10, 16, 25).

The growth and development of this wheat showed that it has been fully "iarovized". Yields of winter wheat that emerged at normal dates in the fall are also included for comparison.

The "natural iarovization" effected in these experiments probably differed slightly from the artificial treatment. But, as will appear later, the difficulties in artificial iarovization are such that it is highly probable that the yields shown here are more favorable for iarovization than would be the case had artificial methods been used. It would seem clear therefore that in the areas represented by these stations iarovization cannot be expected to be of practical value so far as the production of wheat is concerned.

It is seen that the yields of "iarovized" winter wheat, i. e., of that which emerged in the spring, averaged 1.5 bushels per acre less, and are at least slightly less than corresponding yields of spring wheat at all stations except Sheridan, Wyo. They are considerably lower than the corresponding yields of winter wheat which emerged in the fall. Similar but limited results have been previously shown by the writer (20).

In 1933 at Arlington Farm, Rosslyn, Va. (near Washington, D. C.) several varieties of winter and spring oats were iarovized from February 17 to March 27 at about 32° F. They were seeded on April 10, the first favorable opportunity after the treatment ended. Because of this, it was unnecessary to dry the seed before sowing. All varieties headed and matured in a normal manner and the winter varieties showed the typical iarovization response. Yield records were not taken because of bird damage but the crop was estimated at less than 20 bushels per acre. Spring oat varieties seeded March 6 averaged 28.2 bushels per acre and matured earlier than the iarovized oats that were under treatment before the spring oats were sown.

Table 1.--Average yields of fall sown, and late fall or winter sown winter wheat, compared with spring-sown spring wheat during four or more years at eight experiment stations. [Data, except at Lind, Wash., and Lincoln, Nebr., obtained in cooperative experiments and compiled from reports filed in the Division of Cereal Crops and Diseases]

	Lind, Wash.	Moro, Oreg. Plots	Moro, Oreg. Nursery	Moccasin, Mont.	Sheridan, Wyo.	Cheyenne, Wyo.	Akron, Colo.	Highmore, S.Dak.	Lincoln, Nebr.	Weighted Average
Years compared	4 1/	6 2/	2 3/	5 4/	15 5/	14 6/	7 7/	4 8/	5 9/	62
Winter wheat 10/	Yield in bushels per acre									
Fall sown, emerged in fall	19.0	32.8	25.1	23.3	36.7	16.7	23.7	11.5	34.2	25.9
Late fall or winter sown, emerged in spring or late winter	13.0	22.8	22.4	19.1	27.7	10.5	16.2	5.8	11.8	17.5
Spring wheat 11/										
Spring sown	13.2	23.5	29.2	19.6	25.5	11.9	19.0	17.8	14.9	19.0

1/ 1921, 1924, 1927 and 1928. Data compiled from U. S. Dept. Agr. Tech. Bull. 329 (25)
2/ 1916-1918 and 1920-1922.
3/ 1926 and 1927, average of four varieties each of winter and spring wheat.
4/ 1928-1932.
5/ 1918-1932, 4-peck rate of seeding.
6/ 1913, 1915, 1918-1921, 1924-1928, 1930-1932.
7/ 1911-1916, 1918.
8/ 1914-1917.
9/ 1919-1923. "Iarovized" Turkey wheat sown about Feb. 15. Data compiled from Nebr. Research Bull. 31 (16).
10/ Turkey, Kharkof, Kanred or Karmont.
11/ Baart at Lind and Moro; Marquis at Sheridan and Cheyenne; Marquis, Supreme, and Ceres at Moccasin; Pelissier at Akron,; Marquis and Kubanka at Highmore; Java at Lincoln.

Other isolated experiments in various parts of the country could be cited but none is as satisfactory as those mentioned and none support the belief that iarovization can be expected to become a common farm practice.

There is considerable evidence to show that certain spring varieties respond to iarovization treatment when grown subsequently at high temperatures as, for example in the greenhouse or when seeded late in the field. So far as the writer is aware, no such response has been demonstrated when seeded at normal seeding dates.

Stadler (24) has shown that Fulghum oats in Missouri, when seeded late, yields less as compared with other varieties than when seeded early, and Bayles and Martin (8) have demonstrated a similar relation for certain varieties of spring wheat. It is probable that this is largely a temperature relation. If so, iarovization should increase the relative yields of those varieties having low temperature requirements that are not satisfied when seeded late, if a feasible practical method of iarovization not now available were developed. If a satisfactory method were available, there would still need to be considered not only the relative yields of iarovized and untreated seed of the same variety but also of untreated seed of other varieties better suited to late seeding.

IS LOW TEMPERATURE IAROVIZATION FEASIBLE?

What appears to be adequate evidence (22) shows that iarovization of many of the common varieties of winter wheat cannot be successfully completed in less than about 65 days. This involves a serious difficulty where it is expected to use iarovized seed to reseed winter grain that has been killed or badly injured during the winter, for the reason that the extent of damage and hence the necessity of reseeding in many cases cannot be determined in time to complete the iarovization by the normal seeding date. If seeded late, the loss in yield in most cases as compared with spring varieties would no doubt be greater than has already been indicated.

If growing weather occurs during the winter or very early spring so that the extent of winterkilling can be determined in time for ample iarovization, there usually is an opportunity for the satisfactory reseeding of winter grain without treatment. Large acreages of winter wheat were reseeded during the winter in the Columbia Basin of Oregon after the fall sown wheat had been killed by a severe freeze in December, 1924 (8). Winter Turf oats yielded about 66 bushels per acre when sown on February 25, 1931, after the fall sown crop had been winterkilled at Arlington Farm near Washington, D. C. Early spring seeding thus avoids the tediousness and uncertainty of iarovization treatment. The yield secured, however, may not exceed that of a good spring variety sown at the same time.

Turkey winter wheat (8) sown at Moro, Oreg., on April 3, headed in 86 days and matured some seed. In another season it headed in 93 days from sowing on April 9 and yielded 16.5 bushels per acre. Blackhull winter wheat in the same experiments headed in 104 days after sowing on February 22 and yielded 27.5 bushels per acre. These results compare favorably with those obtained elsewhere by seed treatment (22).

Another serious objection to iarovization is the fact that no satisfactory method for treating the seed on a commercial scale has yet been developed. Reports indicate that as much as 10 to 11 hours labor per bushel of wheat is required in Russia in the iarovization process (28). The suggested method of controlling the temperature of a granary without artificial insulation, heat, or refrigeration, within a range of 2° C. or even 5° C., merely by opening and closing doors and windows (21, 28) would appear impossible to anyone familiar with natural temperature fluctuations in the wheat growing areas of the United States. Accurate control of temperature and moisture is necessary to prevent excessive germination, development of molds, and serious injury to the viability of the grain. If conditions are not satisfactory for seeding at the end of the treating period, it may be necessary to dry the seed. In any event, the seed must be dried or the difficulties of seeding moist, partly germinated grain with modern seeding machinery must be considered. Finally, there is the obvious high outlay for temperature control equipment, driers, labor, etc. In short, the difficulties are such and they are so obvious that merely to mention them is probably sufficient to prove to informed agronomists and practical farmers the impracticability of the method in the United States. It is significant that iarovization has not been generally adopted during the approximately 100 years that the treatment has been known in this country.

HIGH TEMPERATURE IAROVIZATION

The essential feature of high temperature iarovization appears to be a retardation of germination in darkness by means of limited moisture and salt solutions (19, 28), for the reason that the temperatures specified (68 to 86°F.) are favorable for rapid germination.

Like low temperature iarovization, the method is not entirely new and there is even less evidence to support the claims made for it. Thus a book published in 1707, containing many unusual agricultural methods compiled from old Latin literature presents the procedure quoted below that bears a close resemblance to a complex high temperature iarovization treatment (27, p.136).

"Take ten bushels of good wheat; and calcine it, till you have reduced it to ashes of a greyish colour. Extract the salt from these ashes; which is done by making a lixivium of them after the usual manner. Instead of water, if you have any May-Dew, or September-Dew, the operation would be incomparably better. Dissolve the salts of the

ashes in rainwater, if you have no Dew; and when the water is impregnated with the salts, of which the ashes are full, you must filter it, and then coagulate. The coagulation is performed by evaporating the humidity. After this you find the salts, which you ought carefully to preserve.

Then take all sorts of dung; (the dung of horses, poultry, pigeons and sheep is best) and put them into a great copper vessel: into which pour one or two pints of brandy, as much dew as you can get, with several pints of white wine. If there be not liquor enough, add some rainwater. Then leave it over a gentle fire for four and twenty hours, and keep stirring it often. Filter the liquor which you preserve for the following use.

Take as much of this liquor as will soak corn enough to sow an of land. Put into it an ounce of salt of wheat, and a pound of nitre. When the salts are quite dissolved, spread the corn upon a sheet, and water it morning and evening for nine days successively with this liquor. The tenth day sow it, one third thinner than usual. The success will pay the trouble, and make large amends for the cost."

The above method includes the following features characteristic of high temperature iarovization (1) limited moisture, (2) salts, (3) similar period of treatment, and (4) germinating temperatures (as indicated by treatment just before sowing time). This treatment lacks only entire darkness instead of the natural day and night to complete the essentials of high temperature iarovization. The ancient elaborate treatmant, it should be noted, was recommended highly but it did not become a general practice.

Apparently some of the reported responses to high temperature iarovization are merely the effect of soaking the seed. The treatment of sorgo seed described below is very similar to iarovization in method and supposed response but it has not become adopted during the 73 years since it was recommended.

"A writer in the Prairie Farmer says, from experiments made last spring, he learned that the seed should be scalded before planting - - - by scalding the seed with hot water, letting it stand in the water ten or twelve hours, then pour the water off and let it stand in a tight vessel in a warm place three or four days, till it has sprouted; then plant on newly prepared land, and it will come up as soon as corn, or some ten days sooner than it would if not scalded". (6)

Unpublished data from tests conducted according to published descriptions of the methods reported to be used in Russia(19, 21, 28) with several crops at a number of experiment stations in the United States in 1933, failed to produce in any significant degree the responses claimed for the high temperature iarovization treatments. Either the high temperature iarovization had little or no effect or the methods were at fault.

The experiments in 1933 included seed of 41 varieties of sorghum sown at two stations which failed to produce earlier heading than untreated seed and which was not affected by treatment to a significant degree in any way except in greatly reduced germination. Other limited experiments gave similar results.

The most constant and universal effect of attempts at iarovization in this country by either high or low temperatures has been the molding and consequent poor germination of the seed. Sorghums are particularly sensitive to seed injury. Very few iarovization experiments thus far attempted could be properly carried out in the field because of the reduced stands from the treated seeds. This alone almost precludes the practical use of known methods of high temperature iarovization.

Field observations furnish additional evidence that the iarovization of sorghums and certain other crops is ineffective. In the Southern Great Plains the soil frequently is too dry at planting time for sorghum plants to emerge until after rains come, although many of the seeds are partly sprouted. Sometimes, as in 1933, plantings made two weeks or a month apart emerge at the same time and subsequently continue at the same stage of development throughout the season. The seeds thus lying in the soil in a partly germinated condition are subjected to all of the factors constituting iarovization, viz, retarded germination for several days, germinating temperatures, limited moisture, darkness, and the presence of salts. In none of the cases observed on experiment stations similar to those described above has there been any indication of a iarovization response.

RESEARCH IN IAROVIZATION

Nothing that has been stated should be interpreted as discouraging the many attempts that are being made to secure a better understanding of what takes place when seed is iarovized. There can be no reasonable doubt that the adaptation of some varieties may be determined in part by their low temperature and and light requirements even though these requirements usually are fully satisfied in good farm practice. A more complete understanding undoubtedly will be of service not only in determining the adaptation of varieties but also in producing new ones.

Also, considerable use of the principles of iarovization could be made in greenhouse culture, especially by plant breeders who wish to grow two generations of winter annuals a year and thus speed up the work. There are important limitations, however, even to this application of iarovization. The crossing of wheat varieties is rather laborious and plant breeders may not wish to risk the loss of crossed seeds as a result of destroyed germination or insufficient treatment in iarovization. In growing an F2 or later generation of winter grain from greenhouse or spring-sown iarovized seed there is no opportunity to observe the cold resistance and normal growing habits of the segregating plants. The later maturity of plants from iarovized wheat as compared with fall-sown seed also may subject the plants to abnormal conditions with respect to rust and high temperatures. However, iarovization should find and already is finding a place in experimental procedure where the above limitations do not prohibit the use of the method.

SUMMARY

Iarovization is a slow and limited germination secured by high or low temperature, a limited moisture supply, and salt solutions. According to published claims, by means of this treatment winter wheat may be successfully seeded in the spring and the growing period of spring wheat and other crops may be materially shortened.

Iarovization is not new, as the principles on which it is based have certainly been known for nearly a century and probably much longer.

No direct evidence regarding the practical value of iarovization is available in the United States. Sixty-two available comparisons of the yield of "naturally iarovized" winter wheat, and of spring wheat seeded in the spring, show that the latter produced the higher average yields.

Iarovized sorghum seed failed to produce earlier heading or better growth than untreated seed of the same varieties in experiments conducted in 1933.

No satisfactory method of iarovizing seed on a commercial scale has yet been devised. The obvious difficulties, such as the necessity for accurate control of temperature, moldy seed, low germination, poor stands, and those inherent in drying the seed or in seeding moist, partly germinated seed are such as to leave little doubt that the method offers nothing of immediate value for the practical farmer.

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